PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : B01D 19/00	A1	(11) International Publication Number: WO 95/06506 (43) International Publication Date: 9 March 1995 (09.03.95)

(21) International Application Number: PCT/US94/09118

(22) International Filing Date: 12 August 1994 (12.08.94)

(30) Priority Data:
08/116,095 2 September 1993 (02.09.93) US

(71) Applicant: ABBOTT LABORATORIES [US/US]; 1212 Terra Bella Avenue, Mountain View, CA 94043 (US).

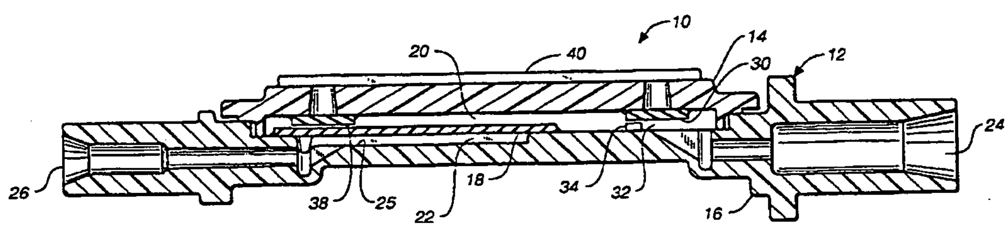
(72) Inventors: BRYANT, Peter, L.; 835A Country Club Drive, Libertyville, IL 60048 (US). CARON, Lois, L.; 703 W. Florence Drive, McHenry, IL 60050 (US).

(74) Agents: THIBAULT, Harry, G.; Abbott Laboratories, Dept. 377/Building 850, 1212 Terra Bella Avenue, Mountain View, CA 94043 (US) et al.

(81) Designated States: AU, CA, JP, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(54) Title: GAS-SEPARATING FILTER



(57) Abstract

A gas-separating filter assembly (10) has cooperating hydrophobic (30, 38) and hydrophilic (18) membranes. Hydrophilic membrane (18) separates inlet chamber (20) from outlet chamber (22). Two vent openings (28, 36) are in housing (12) adjacent inlet chamber (20) for venting same. First vent opening (28) is upstream of hydrophilic membrane (18) and adjacent inlet port (24) joined in fluid flow communication with inlet chamber (20). Second vent opening (36) is at the opposite end of inlet chamber (20). Each vent opening (28, 36) is covered by hydrophobic membranes (30, 38), respectively. Substantially all gas and air is separated from the liquid flow by passage adjacent to hydrophobic membrane (30), with passage through hydrophilic membrane (18) disposed downstream thereof desirably providing redundant filtering action for consistent and reliable operation.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	GB	United Kingdom	MR	Mauritania
AU	Australia	GE	Georgia	MW	Malawi
BB	Barbados	GN	Guinea	NE	Niger
BE	Belgium	GR	Greece	NL	Netherlands
BF	Burkina Faso	HU	Hungary	NO	Norway
BG	Bulgaria	IE	Ireland	NZ	New Zealand
BJ	Benin	IT	Italy	PL	Poland
BR	Brazil	JP	Japan	PT	Portugal
BY	Belarus	KE	Kenya	RO	Romania
CA	Canada	KG	Kyrgystan	RU	Russian Federation
CF	Central African Republic	KP	Democratic People's Republic of Korea	SD	Sudan
CG	Congo			SE	Sweden
CH	Switzerland	KR	Republic of Korea	SI	Slovenia
CI	Côte d'Ivoire	KZ	Kazakhstan	SK	Slovakia
CM	Cameroon	LI	Liechtenstein	SN	Senegal
CN	China	LK	Sri Lanka	TD	Chad
CS	Czechoslovakia	LU	Luxembourg	TG	Togo
CZ	Czech Republic	LV	Latvia	TJ	Tajikistan
DE	Germany	MC	Monaco	TT	Trinidad and Tobago
DK	Denmark	MD	Republic of Moldova	UA	Ukraine
ES	Spain	MG	Madagascar	US	United States of America
FI	Finland	ML	Mali	UZ	Uzbekistan
FR	France	MN	Mongolia	VN	Viet Nam
GA	Gabon				

GAS-SEPARATING FILTER

Field Of The Invention

This invention relates generally to filter devices and, more particularly, to an intravenous gas-separating filter device employing a hydrophobic membrane which is configured for use such that substantially all gas is separated and vented at the hydrophobic membrane. This device can include a hydrophilic membrane for particulate filtering and redundancy of the gas-separating function.

Background Of The Invention

When fluids, such as blood, plasma, or other solutions, are introduced into the body intravenously, it is important to remove any gas or air suspended in the fluid and thereby eliminate any risk of an embolism from gas or air reaching the patient. The removal of such gas or air from the fluid is typically accomplished by use of a gas-separating filter.

The typical features of intravenous gas-separating filters include an inlet chamber and an outlet chamber separated by a hydrophilic membrane. The hydrophilic membrane permits the passage of liquid and prevents the passage of gas. Thus, liquid passes through the hydrophilic membrane from the inlet chamber to the outlet chamber while gas is retained in the inlet chamber and vented to atmosphere.

In some constructions, a hydrophobic membrane is employed in connection with a vent in the inlet chamber in order to vent the gas which collects in the inlet chamber. See for example U.S. Patent Nos. 4,906,260, 4,190,426, and 3,854,907.

It is desirable to configure an intravenous gas-separating filter device so that it will start up

(conventionally referred to as "priming") and function in any orientation relative to the ground. A relatively low internal volume device having an inlet chamber with a minimal volume is preferable in order to minimize the amount of air that must be initially vented from the inlet chamber. In use, a low internal volume filter can be quickly primed and initially vented.

In the prior art, gas-separating filter devices are dependent upon the integrity of the hydrophilic membrane separating the inlet chamber from the outlet chamber. A disintegration or absence of the hydrophilic membrane in prior art filters would cause them to malfunction. It would be desirable to construct a filter that would continue to filter air or gas from the liquid in the event of disintegration or absence of the hydrophilic membrane. It would be desirable to separate gas and air from liquid in the inlet chamber prior to its passage through the hydrophilic membrane, thereby desirably providing a redundant filtering action for consistent and reliable operation.

Summary Of The Invention

The gas-separating filter device in accordance with the present invention is configured for highly reliable and consistent filtering of gas and air. Significantly, this is achieved by providing a hydrophobic membrane in operative association with a vent opening, with control of liquid flow cooperating with the venting arrangement to substantially completely effect filtering and venting of all gas through the vent opening. While it is presently preferred that the present filter also be provided with a hydrophilic membrane to facilitate particulate filtering, it is specifically contemplated that gas separation be

substantially completely effected without reliance upon the hydrophilic membrane.

The filter device in accordance with the illustrated embodiment of the invention includes a filter housing having a cover portion and a base portion in confronting relationship with each other. A hydrophilic filter membrane is interposed between the cover and base portions of said housing and thereby defines an inlet chamber and an outlet chamber. An inlet port is joined in fluid flow communication with the inlet chamber. An outlet port is joined in fluid flow communication with the outlet chamber.

A first vent opening communicates with the inlet chamber upstream of the hydrophilic filter membrane for venting gas from liquid passing through the filter assembly. A hydrophobic filter membrane is positioned adjacent to said vent opening for preventing liquid from flowing through the vent opening while permitting gas flow therethrough so that gas is separated from liquid flow.

A second vent opening communicates with the inlet chamber substantially adjacent the hydrophilic membrane downstream of the first vent opening. A second hydrophobic filter membrane is adjacent the second vent opening for permitting flow of gas (but not liquid) therethrough and thereby initially venting air from the inlet chamber during initial flow of liquid into the filter assembly.

The separation of gas from liquid flowing adjacent the first vent opening is promoted by a relatively narrow liquid flow region adjacent the first vent opening. A weir element may optionally be employed to define the narrow liquid flow region.

In an alternative aspect of the invention, at least one stand-off projection on the exterior of the

housing is positioned in proximity to the vent openings to inhibit exterior blockage of the openings. Preferably, a pair of stand-off projections are positioned in flanking relationship to the vent openings.

In a preferred embodiment, the filter assembly is substantially disc-shaped. Inlet and outlet ports are diametrically opposed on opposite ends of the housing. The first and second vent openings are generally aligned with the inlet and outlet ports. The stand-off projections are generally aligned with the inlet and outlet ports in flanking relationship to the vent openings. The hydrophilic filter membrane is D-shaped.

In another aspect of the invention, the filter assembly has a separation chamber having a vent opening wherein the back pressure in the filter combined with the narrow flow region in the separation chamber and a sufficient residence time within the chamber cause all gas in the fluid/gas mixture to pass through the vent opening.

Other features and advantages of the present invention will become readily apparent from the following detailed description, the accompanying drawings, and the appended claims.

Brief Description Of The Drawings

FIG. 1 is a perspective view of a intravenous gas-separating filter device in accordance with the invention;

FIG. 2 is an exploded perspective view of the filter device shown in FIG. 1;

FIG. 3 is a cross-sectional view taken along the line 3-3 in FIG. 1;

FIG. 4 is a cross-sectional view taken along the line 4-4 in FIG. 1;

FIG. 5 is a cross-sectional elevational view of a model filter device in accordance with the invention;

FIG. 6 is a cross-sectional view taken along the line 6-6 in FIG. 5;

FIG 7. is a model filter device as shown in FIG. 5 wherein a gas film is venting; and

FIG. 8 is a model filter device as shown in FIG. 5 wherein a gas bubble is venting.

Detailed Description Of The Invention

The following is a detailed description of the invention. The detailed description is not intended to be an exhaustive description of all embodiments within the scope of the invention and is not intended to limit the scope of the claims to the disclosed embodiments. Other embodiments within the scope of the claims will be apparent to those skilled in the art.

Referring to FIGS. 1 and 2, the gas-separating filter assembly 10 in accordance with the invention includes a filter housing 12 comprising a cover portion 14 and a base portion 16 which are fitted together in confronting relationship with each other. Preferably, the cover and base portions are constructed from a rigid, clear plastic material such as an acrylic polymer. However, any rigid transparent material suitable for medical use can be used.

A hydrophilic filter membrane 18 is interposed between the cover 14 and base 16 portions. Preferably, the hydrophilic filter membrane is a polycell foam material such as Supor material sold by Gelman Sciences, Inc. of Ann Arbor, Michigan. However, any hydrophilic membrane material permitting passage of liquid and

preventing passage of gas suitable for medical use can be used. In a preferred embodiment, the hydrophilic filter membrane 18 is generally D-shaped, as shown in FIG. 2.

Referring to FIG. 3, the hydrophilic filter membrane 18 is secured to the base portion 16. The filter membrane 18 may be heat sealed to the base portion 16 or with an adhesive suitable for medical use. The hydrophilic filter membrane 18 divides the housing 12 into an inlet chamber 20 and an outlet chamber 22.

Referring to FIG. 4, a plurality of upstanding ribs 23 extend upwardly from the base portion 16 to support the hydrophilic filter membrane 18. A plurality of grooves 25 are defined between the ribs 25 to receive fluid in the outlet chamber 22 and direct it to an outlet port 26 (FIGS. 2 and 3).

Referring to FIG. 3, an inlet port 24 is defined on one end of the base portion 16. The inlet port 24 is joined in fluid communication with the inlet chamber 20. An outlet port 26 is defined at the opposite end of the base portion 16. The outlet port 26 is joined in fluid communication with the grooves 25 of the outlet chamber 22. Thus, the inlet 24 and outlet 26 ports accommodate the flow of liquid through the filter assembly 10 from the inlet port 24 to the outlet port 26.

In a current embodiment, the disc-shaped filter housing is approximately 1-5/16 inches in diameter and 5/32 inches thick. The inner diameter of the inlet port is approximately 1/8 inches and the inner diameter of the outlet port is approximately 3/32 inches. The inlet and outlet ports may be configured to fit as luer fittings (not illustrated) or tube fittings.

A first vent opening 28 is defined in the cover portion 14 adjacent the inlet port 24 (FIG. 3).

In a current embodiment, the first vent opening 28 is provided with a diameter of 0.051 inches, with a 5 degree taper, as shown. The first vent opening 28 communicates with the inlet chamber 20 at a location that is upstream of the hydrophilic filter membrane 18. Liquid entering the inlet chamber 20 passes by the first vent opening 28 before it flows to the hydrophilic filter membrane 18.

A first hydrophobic filter membrane 30 is positioned adjacent the first vent opening 28 (FIG. 3). Preferably, the first hydrophobic membrane 30 is one manufactured from Teflon™ fibers. However, any hydrophobic membrane material that permits the passage of gas and prevents the passage of liquid and is suitable for medical use can be used. The first hydrophobic filter membrane 30 is secured to the cover portion 14 by heat sealing the components or with an adhesive suitable for medical use.

The first hydrophobic filter membrane 30 permits the passage of gas therethrough out of the inlet chamber 20 through the first vent opening 28. Thus, gas is separated from liquid flow at the first vent opening 28 prior to flow of the liquid to the hydrophilic filter membrane 18.

In a preferred embodiment, referring to FIG. 3, the inlet chamber 20 defines a relatively narrow liquid flow region 32 adjacent the first vent opening 28. A narrow liquid flow region causes any gas or air entrapped in the liquid flow to pass adjacent the first hydrophobic membrane 30 and through said first vent opening 28. The depth of the liquid flow region 32 may be in the range of about 0.015 inches to about 0.060 inches and preferably is about 0.045 inches.

In an alternative embodiment, the narrow liquid flow region 32 may be defined in part by an

upstanding weir 34 element (shown in phantom lines in FIG. 3).

A second vent opening 36 is defined in the cover portion 14 adjacent the hydrophilic filter membrane 18. Preferably, the vent opening 36 also has a diameter on the order of 0.051 inches, with a 5 degree taper. A second hydrophobic filter membrane 38 is secured, for example heat-sealed, to the cover portion 14 and extends across said second vent opening 36 for permitting passage of gas and preventing passage of liquid therethrough.

The second vent opening 36 permits the quick evacuation of air in the inlet chamber 20 during the initial introduction of fluid into the filter assembly 10. Preferably, the second vent opening 36 is positioned in the inlet chamber 20 at an end opposite the location of the first vent opening 28.

Stand-off projections 40 are located on the exterior of the cover portion 14 in flanking relationship to the vent openings 28 and 36. The stand-off projections 40 inhibit exterior blockage of the vent openings 28 and 36 when the filter assembly 10 is placed adjacent the skin of the patient or another surface which may potentially cover or block the vent openings 28 and 36.

The construction of the housing 12 and the outlet port 26, an external or internal restrictor or a valve can create a back pressure within the filter assembly 10. Preferably, the back pressure is in the range of 5-15 psig or, more preferably, 10-11 psig. Preferably the resulting flow rate is in the range of 0.1 cc/hour to 400 cc/hour thus creating sufficient residence time within the filter assembly 10 to substantially separate all gas from the liquid and pass the gas through the first vent opening 28. Concomitant

with the back pressure in the filter, the required vent pressure in the vent membrane is adjusted to provide ready venting. This adjustment is made by controlling the porosity of the vent membrane to contain the fluid and vent the air by back pressure. In some cases, a bacteria barrier is also effected. In a preferred embodiment, the porosity is. 45 microns.

In operation, the filter assembly 10 is connected to an intravenous solution supply at the inlet port 24. An intravenous catheter device (not illustrated) is connected to the outlet port 26. Liquid flows into the inlet port 24 and through the filter device 10. The filter device 10 is self-priming and functional in any orientation. When liquid initially flows into the filter assembly 10, air is purged from the inlet chamber 20 through the first and second vent openings 28 and 36. As liquid enters the inlet chamber 20, it passes adjacent the first hydrophobic member 30 adjacent the first vent opening 28. The combination of a sufficient back pressure, residence time and narrow fluid flow region 32 adjacent the first vent opening 28 forces all gas or air entrapped in the fluid to pass through the first hydrophobic member 30 and out of the first vent opening 28. Thus, the hydrophilic membrane 18 acts as a redundant filter means providing a back-up filtering function within the filter assembly.

The principle of the invention is described below quantitatively with reference to a model filter as illustrated in FIG. 5-8.

Referring to FIGS. 5 and 6, the model filter 100 has a separation chamber 103 having rectangular cross-section of length L, height H and width W. The fluid retentive membrane at vent 102 permits venting of gas while retaining fluid at a given back pressure P_B. A fluid/gas mixture flows from right to left through the

separation chamber 103. A gas element 104 is shown entering the separation chamber 103 at the bottom of the separation chamber 103.

The following notation for various parameters is used in the model and indicated in FIGS. 5-8:

Q_{GV}	=	volumetric flow rate of gas through the vent 102
V_{GV}	=	velocity of gas through vent
$Q_{F/G}$	=	volumetric flow rate of liquid/gas mixture through the filter 100
V_{GN}	=	velocity of gas normal to liquid/gas flow and toward vent membrane 102
P_B	=	back pressure
$¢_m$	=	a constant characterizing the vent membrane
T_1	=	time for the gas element 104 to travel to and through vent member 102
T_2	=	time for the liquid/gas mixture to travel through the separation chamber 103

For complete venting of gas from the separation chamber 103, the time T_1 for the gas element 104 to travel to and through the vent membrane 102 must be less than the time T_2 for the gas/liquid mixture to travel through the separation chamber 103. The gas can vent as a film extending across the height H of the chamber 103 or as a bubble, as discussed below.

A gas film 106 extending across the height H of the chamber 103 is illustrated in FIG. 7. In such case, $V_{GV} = V_{GN}$.

For any filter member characterized by a constant $¢_m$, the following holds true:

$$Q_{GV} = ¢_m \text{ (Area) (Pressure Differential)}$$

or

$$Q_{GV} = ¢_m \, WL \, P_B$$

Therefore,

$$V_{GV} = \frac{Q_{GV}}{WL} = ¢_m \, P_B$$

and the time T_1 for the gas element 104 of the film 106 in FIG. 7 to travel across the separation chamber 103 and through the vent 102 is as follows:

$$T_1 = \frac{H}{V_{GN}} = \frac{H}{V_{GV}} = \frac{H}{¢_m \, P_B}$$

The time T_2 for the liquid/gas mixture to travel through the separation chamber 103 is a function of $V_{F/G}$ and L. Therefore,

$$T_2 = \frac{L}{V_{F/G}} = \frac{L}{\frac{Q_{F/G}}{HW}} = \frac{LHW}{Q_{F/G}}$$

Since T_1 must be less than T_2, then

$$\frac{H}{¢_m \, P_B} < \frac{LHW}{Q_{F/G}} \text{ or } \frac{1}{¢_m \, P_B} < \frac{LW}{Q_{F/G}}$$

This is the relationship between parameters for film venting of a filter device in accordance with the invention.

Referring to FIG. 8 for the case of bubble venting, V_{GN} depends upon where the bubble 108 is located. When it is against the vent 102, $V_{GN} = V_{GV}$ as in the case of film venting discussed above.

When the bubble 108 is in the fluid and spaced from the vent 102, it has a V_{GN} denoted V_B. V_B is determined by turbulence, fluid deflection, natural migration of gas toward the vent, and orientation with respect to gravity. The bubble 108 must travel a distance H-D at a velocity V_B in order to reach the vent 102 and then travel through the vent 102 a distance D in order to pass from the separation chamber 103 through the vent 102. Therefore, the time T_1 for the bubble to travel to and through the vent member 102 is as follows:

$$T_1 = \frac{H-D}{V_B} + \frac{D}{V_{GV}} = \frac{H-D}{V_B} + \frac{D}{\text{¢}_m\ P_B}$$

T_1 must be less than T_2 as discussed above. $T_2 = \frac{LHW}{Q_{F/G}}$. Since $T_1 < T_2$, then

$$\frac{H-D}{V_B} + \frac{D}{\text{¢}_m\ P_B} < \frac{LHW}{Q_{F/G}}$$

This is the relationship between parameters for bubble venting of a filter device in accordance with the invention.

Note that when H = D , then film venting occurs and the above relationship between parameters for bubble venting reduces to the relationship between parameters for film venting, i.e. $\frac{1}{\text{¢}_m\ P_B} < \frac{LW}{Q_{F/G}}$.

The velocity V_B of the bubble can be increased by directing flow of fluid/gas mixture against the vent 102 with ramps, weirs, etc. V_B can be optimized empirically.

Better venting can be achieved by increasing T_2 relative to T_1. This can be achieved by reducing H or $Q_{F/G}$, and/or increasing V_B, ¢_m, P_B, L or W.

Film venting is not sensitive to orientation relative to gravity and is easier to control than bubble venting.

In an anticipated embodiment of a filter in accordance with the invention, a saline solution is the anticipated fluid in a filter having the following parameters:

H = .031 inches

¢_m = $\frac{.55 \text{ Free L}}{\text{min-cm}^2\text{-Psi}} = 19.6 \times 10^3\ \frac{\text{cc at 10 Psi}}{\text{Hr-cm}^2}$

P_B = 10 Psig

$Q_{F/G}$ = 500 cc/hr

L = .2 inches = .508 cm

W = .1 inches = .254 cm

Thus, for film venting,

$$T_1 = \frac{1}{¢_m \; P_B} = 5.1 \times 10^{-6} \text{ Hr}$$

and

$$T_2 = \frac{LW}{Q_{P/G}} = 2.6 \times 10^{-4} \text{ Hr}$$

T_1 is less than T_2, which should vent, and has been tested to do so.

For bubble venting, controlling the parameters to fall within the ranges shown below is the anticipated construction for filters for medical use and should provide complete venting:

H: .010-0.50 inches
W: 0.20-1.00 inches
L: 0.1-6.00 inches
P_B: 2-20 Psig
$¢_m$: 1-52 $\frac{\text{Free liters}}{\text{min-cm}^2\text{-10 Psi}}$
D: .001-.050 inches
$Q_{P/G}$: .1-1000 cc/hr
V_B: 0-4.4 x 10^5 cm/min

The filter of the present invention can be used in a variety of medical applications where fluids are administered, as for example, in the intravenous administration of blood, plasma, drugs or saline.

From the foregoing, it will be observed that numerous modifications and variations can be effected without departing from the true spirit and scope of the novel concept of the present invention. It is to be understood that no limitation with respect to the specific embodiment is intended or should be inferred. The disclosure is intended to cover by the appended claims all such modifications as fall within the scope of the claims.

WHAT IS CLAIMED IS:

1. A gas separating filter assembly comprising:

a filter housing including a cover portion and a base portion positioned in confronting relationship with each other, said housing including an inlet chamber and an outlet chamber downstream of and in fluid communication with said inlet chamber;

an inlet port joined in fluid flow communication with said inlet chamber and an outlet port joined in fluid flow communication with said outlet chamber accommodating flow of liquid through said filter assembly;

a first vent opening defined by said housing and communicating with said inlet chamber for venting gas from liquid passing through said filter assembly; and

a first hydrophobic filter membrane positioned within said housing adjacent said first vent opening for preventing liquid from flowing through said first vent opening while permitting gas flow therethrough, said inlet chamber and said vent opening cooperating so that substantially all gas is separated from liquid flow through said filter assembly by passing through said hydrophobic filter membrane and said first vent opening prior to flow of the liquid from said inlet chamber to said outlet chamber and out of said filter assembly.

2. A gas separating filter assembly in accordance with claim 1 wherein said housing defines a second vent opening communicating with said inlet chamber downstream of said first vent opening; and

said filter assembly includes a second hydrophobic filter membrane positioned within said

housing adjacent said second vent opening for permitting flow of gas therethrough during initial flow of liquid into said filter assembly.

3. A gas separating filter assembly in accordance with claim 1 wherein said inlet chamber defines a relatively narrow liquid flow region adjacent said first vent opening for promoting separation of gas from liquid flowing through said filter assembly, wherein the depth of said liquid flow region is in the range of about 0.015 inches to about 0.060 inches.

4. A gas separating filter assembly in accordance with claim 3 wherein said liquid flow region is defined in part by an upstanding weir element.

5. A gas separating filter assembly in accordance with claim 1 including at least one stand-off projection on the exterior of said housing in proximity to said first vent opening to inhibit exterior blockage of said opening.

6. A gas separating filter assembly in accordance with claim 1, including a hydrophilic filter membrane interposed between said cover and base portions of said housing so that said inlet chamber is disposed upstream of said hydrophilic filter membrane, and said outlet chamber is disposed downstream of said hydrophilic filter membrane.

7. A gas separating filter assembly in accordance with claim 6 wherein said hydrophilic filter membrane is D-shaped.

8. A gas separating filter assembly in accordance with claim 2 wherein said inlet and outlet ports are diametrically opposed on opposite ends of said housing, and said first and second vent openings are generally aligned with said inlet and outlet ports.

9. A method of separating gas from liquid through use of a filter assembly in accordance with claim 1 including flowing liquid through said filter assembly at a flow rate between about 0.1 cc/hour to about 400 cc/hour to create sufficient residence time of liquid within said filter assembly to separate substantially all gas from the liquid and pass said gas through said first vent opening.

10. A method of separating gas from liquid in accordance with claim 9 including the further step of providing said first vent opening with a diameter of about 0.051 inches.

11. A method in accordance with claim 9 wherein the vent pressure internal to the filter and the resistance of the vent to the passage of air are selected to provide ready venting.

12. A gas separating filter assembly comprising:

a separation chamber for receiving a flow of fluid/gas mixture and separating the gas from the liquid in said mixture, said separation chamber having an effective length L, an effective height H, and an effective width W; said separation chamber being defined by a floor, two side walls and a ceiling;

said ceiling being a fluid retentive membrane having said length L and said width W, said

fluid retentive membrane being a gas separation filter for permitting the passage of gas therethrough while preventing the passage of liquid therethrough when said liquid/gas mixture is at a pressure P_B;

said liquid/gas mixture having a volumetric flow rate $Q_{F/G}$ and a velocity $V_{F/G}$ through said separation chamber;

said gas having a volumetric flow rate Q_{GV} and a velocity V_{GV} through said filter;

said filter being characterized by a constant $¢_m$ that equals $\frac{Q_{GV}}{WLP_B}$;

said liquid/gas mixture having gas bubbles, said gas bubbles having a diameter D, said bubbles having a velocity V_B normal to the flow of the liquid/gas mixture and toward said membrane;

said filter device being configured wherein

$$\frac{H-D}{V_B} + \frac{D}{¢_m\ P_B} \text{ is less than } \frac{LHW}{Q_{F/G}}$$

13. A gas separating filter assembly in accordance with claim 12 wherein said height H is in the range of about .010 inches to about .50 inches.

14. A gas separating filter assembly in accordance with claim 12 wherein said width W is in the range of about .20 inches to about 1 inch.

15. A gas separating filter assembly in accordance with claim 12 wherein said length L is in the range of about 0.1 inches to about 6 inches.

16. A gas separating filter assembly in accordance with claim 12 wherein said pressure P_B is in the range of about 2 Psig to about 20 Psig.

17. A gas separating filter assembly in accordance with claim 12 wherein said ¢_m is in the range of about 1 $\frac{\text{Free liters}}{\text{min-cm}^2\text{-10 Psi}}$ to about 52 $\frac{\text{Free liters}}{\text{min-cm}^2\text{-10 Psi}}$.

18. A gas separating filter assembly in accordance with claim 12 wherein said D is in the range of about .001 inches to about .050 inches.

19. A gas separating filter assembly in accordance with claim 12 wherein said $Q_{F/G}$ is in the range of about .1 cc/hr to about 1000 cc/hr.

20. A gas separating filter assembly in accordance with claim 12 wherein said V_B is in the range of zero to about 4.4 x 10^5 cm/min.

21. A gas separating filter in accordance with claim 12 wherein D equals H.

22. A gas separating filter assembly comprising:

a separation chamber for receiving a flow of liquid/gas mixture and separating the gas from the liquid in said mixture, said separation chamber having a relatively narrow flow region and a vent opening adjacent said chamber for permitting gas to exit said chamber while retaining liquid within said chamber, said flow having a residence time within said chamber and adjacent said vent, said residence time being sufficient to permit all gas passing through said chamber to exit through said vent.

23. A gas separating filter assembly comprising:

a filter housing including a cover portion and a base portion positioned in confronting relationship with each other and defining a separation chamber having a relatively narrow fluid flow region;

an inlet port joined in fluid flow communication with said chamber and an outlet port joined in fluid flow communication with said chamber accommodating flow of a liquid/gas mixture through said filter assembly;

a vent opening defined by said housing and communicating with said narrow flow region for venting gas from said liquid/gas mixture flowing through said filter assembly, said vent opening being configured wherein all liquid/gas mixture flowing through said filter device passes adjacent said vent opening; and

a membrane means extending across said vent opening for drawing gas from said liquid/gas mixture and retaining all liquid in said mixture within said chamber as said mixture passes adjacent said vent;

said flow of liquid/gas mixture having a sufficient back pressure and residence time in said narrow flow region wherein all gas in said liquid/gas mixture in said filter device is drawn through said vent opening as said mixture passes through said narrow flow region.

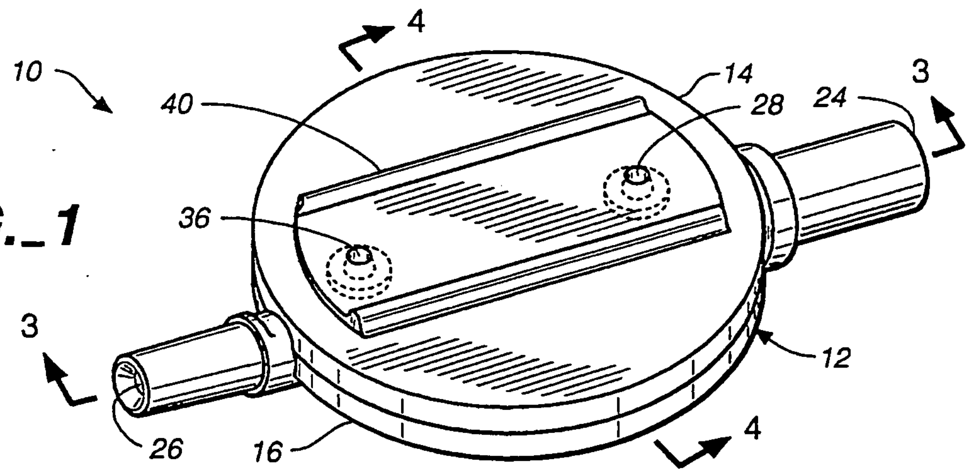


FIG._1

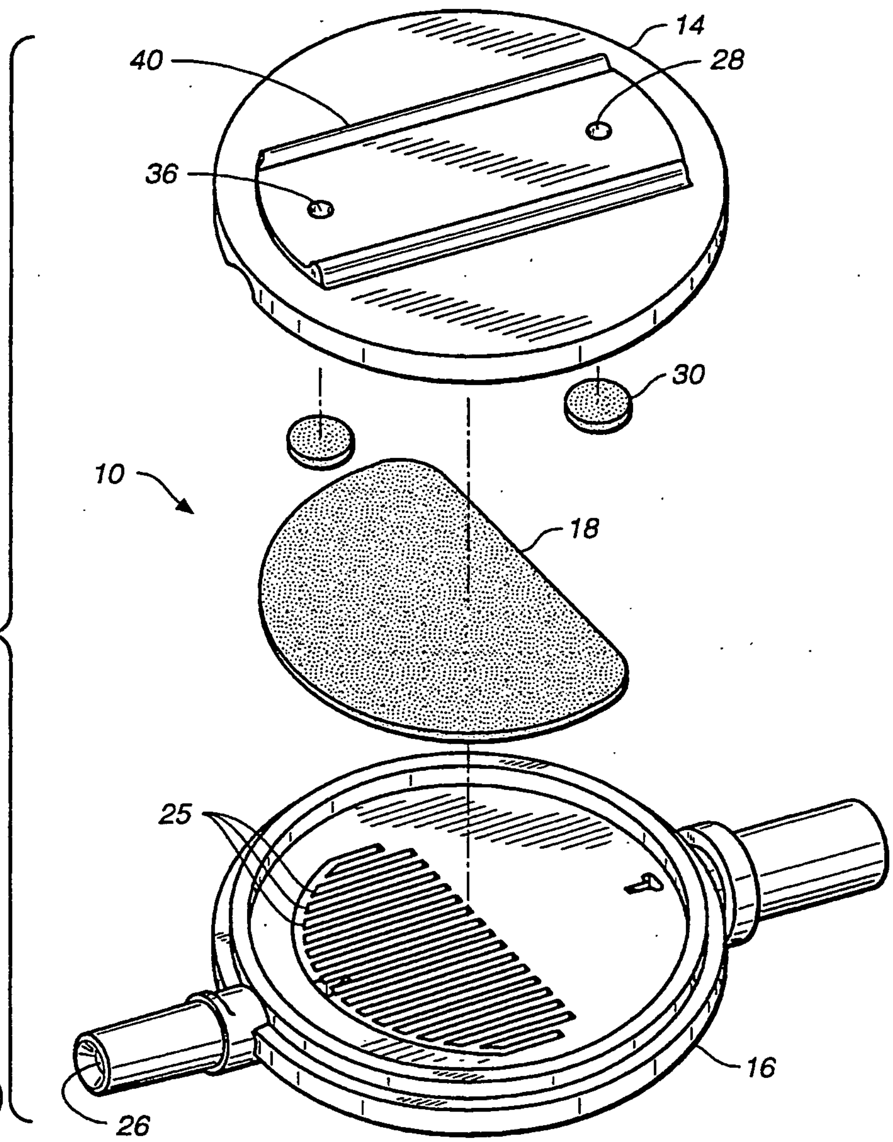


FIG._2

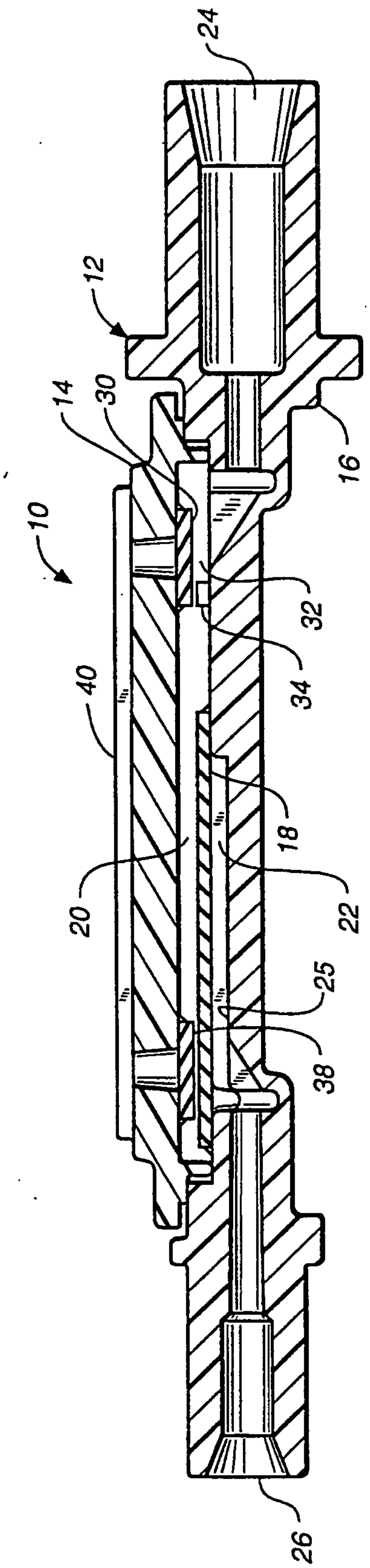

24
12
14
30
16
10
32
34
40
18
20
22
25
38
26

FIG._3

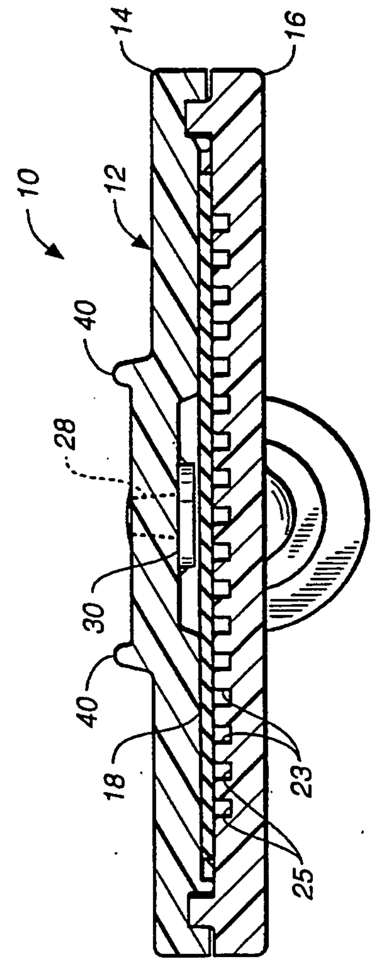

14
16
10
12
40
28
30
40
18
23
25

FIG._4

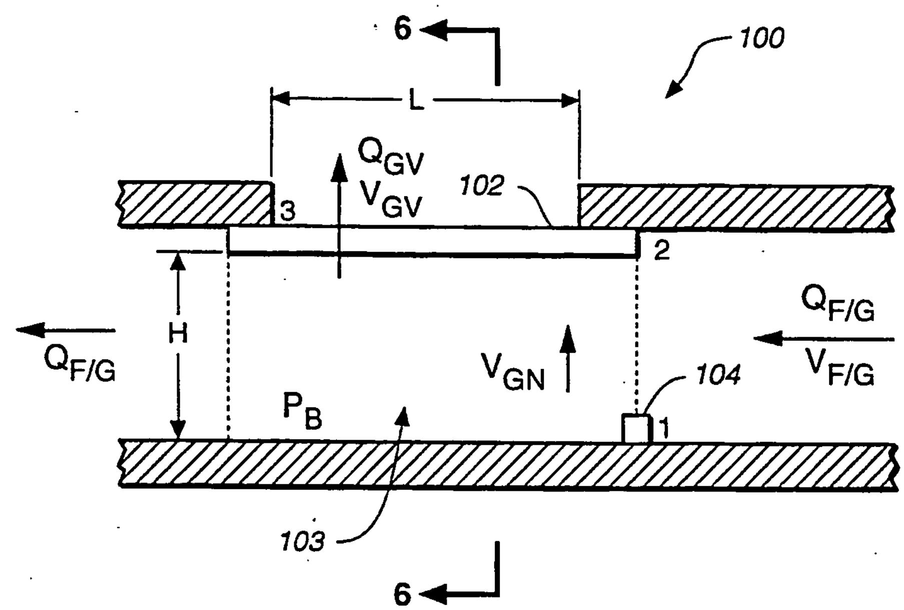

6
100
L
Q_{GV}
V_{GV}
102
3
2
$Q_{F/G}$
H
$Q_{F/G}$
V_{GN}
104
$V_{F/G}$
P_B
1
103
6

FIG._5

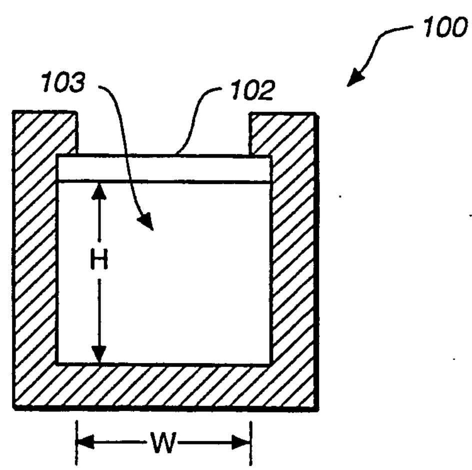

100
103
102
H
W

FIG._6

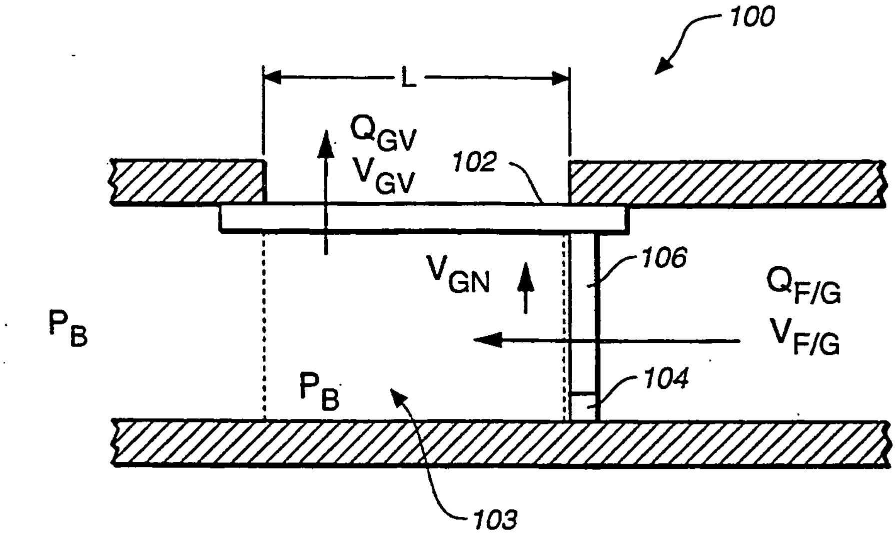

100
L
Q_{GV}
V_{GV}
102
V_{GN}
106
$Q_{F/G}$
$V_{F/G}$
P_B
P_B
104
103

FIG._7

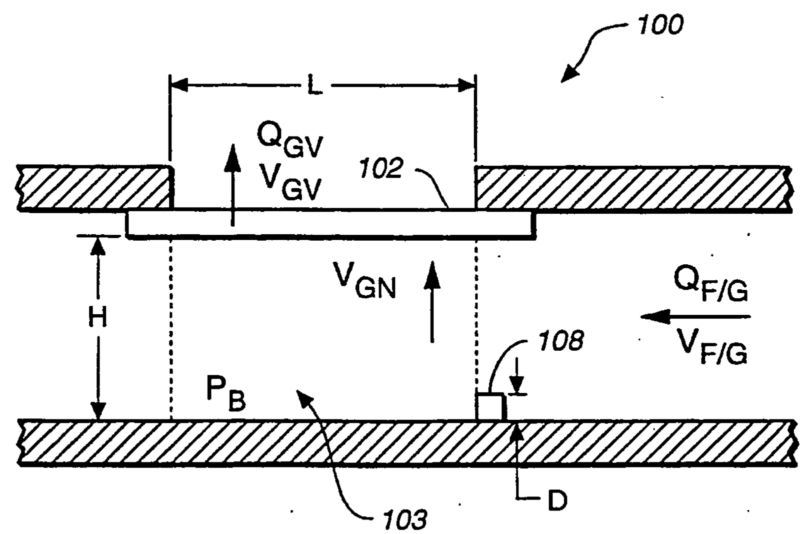

100
L
Q_{GV}
V_{GV}
102
H
V_{GN}
$Q_{F/G}$
$V_{F/G}$
108
P_B
D
103

FIG._8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/09118

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :BOID 19/00
US CL :95/46; 96/6; 55/321
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 95/46, 241, 260, 279; 96/6, 189, 219; 55/301, 321, 482

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US, A, 3,803,810 (ROSENBERG) 16 APRIL 1974, the entire document.	1-2, 5-6, 8-9, 12, 22 3-4, 7, 10-11, 13-21, 23
A	US, A, 3,905,905 (O'LEARY ET AL) 16 September 1975.	1-23
A	US, A, 4,177,149 (ROSENBERG) 04 December 1979.	1-23
A	US, A, 4,190,426 (RUSCHKE) 26 February 1980.	1-23
A	US, A, 4,294,594 (SLOANE, JR. ET AL) 13 October 1981.	1-23

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be part of particular relevance
- "E" earlier document published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search 17 OCTOBER 1994	Date of mailing of the international search report 22 NOV 1994
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer Debbie Thomas ROBERT H. SPITZER for Telephone No. (703) 308-3794

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 4,906,260 (EMHEISER ET AL) 06 March 1990.	1-23